

Orientation effect on Cryogenic Pipe Chilldown Experiments

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Content

Experiment System

Flow pattern

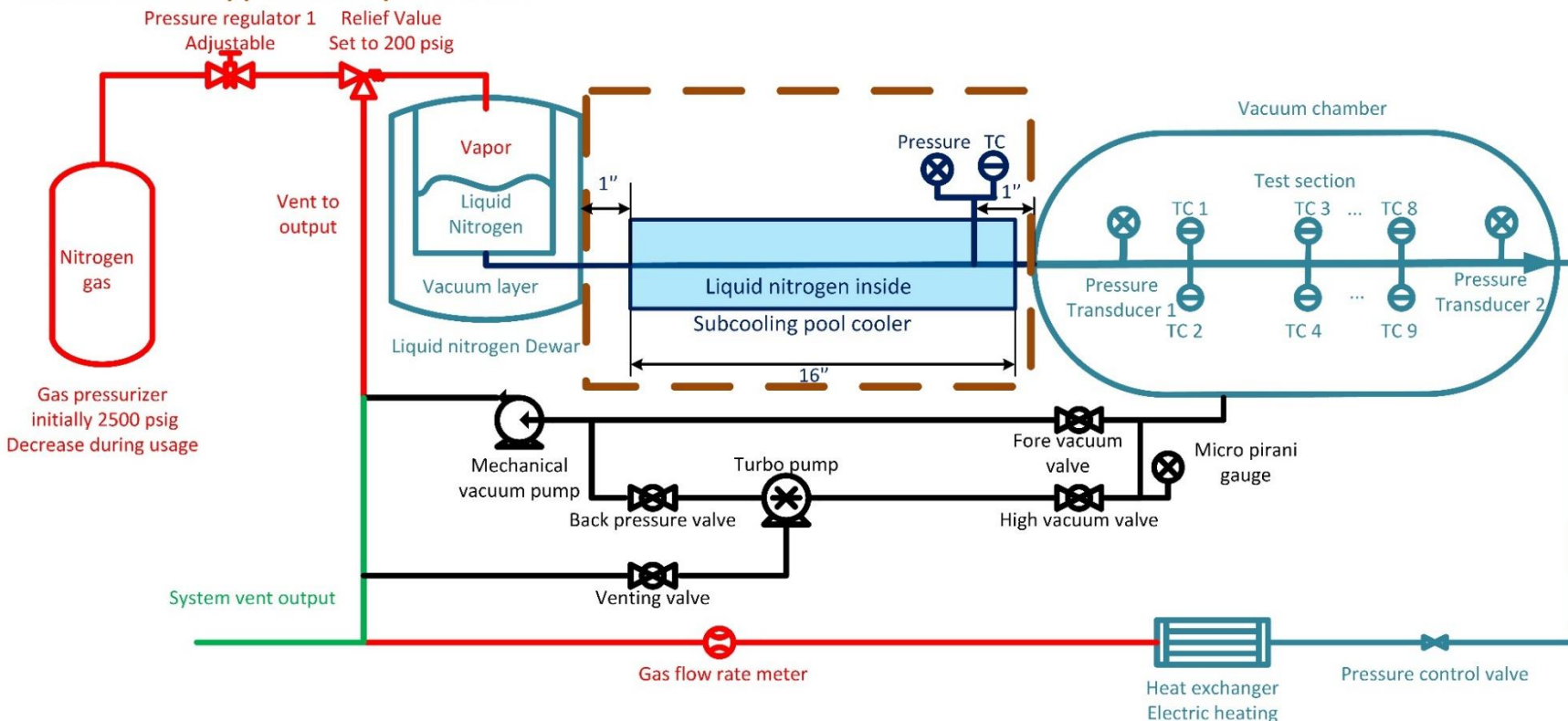
Heat Transfer Characteristic

Conclusion

Experimental System

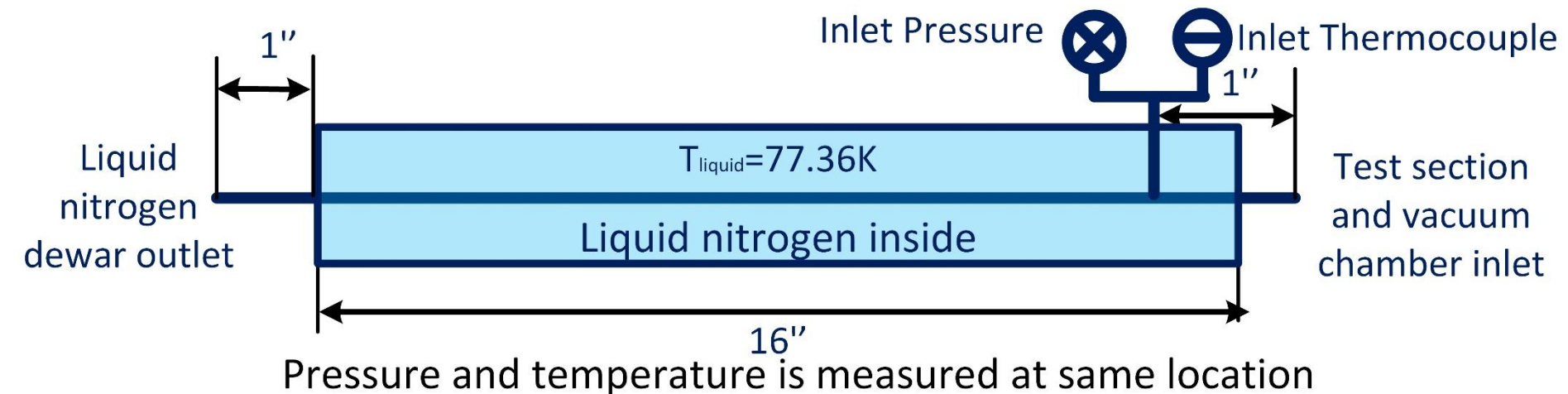
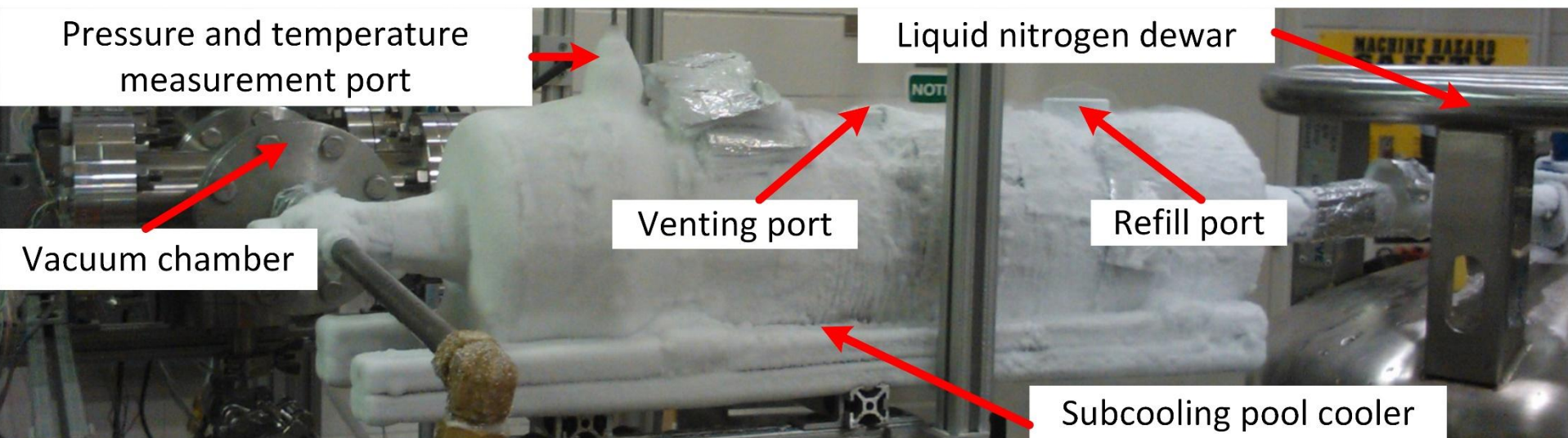
Overall design

Dark blue lines: liquid nitrogen precool lines
Red lines: nitrogen gas lines
Green: mixed venting gas lines
Blue lines: liquid nitrogen transport lines
Black lines: air lines
Brown circles: apparatus improvement



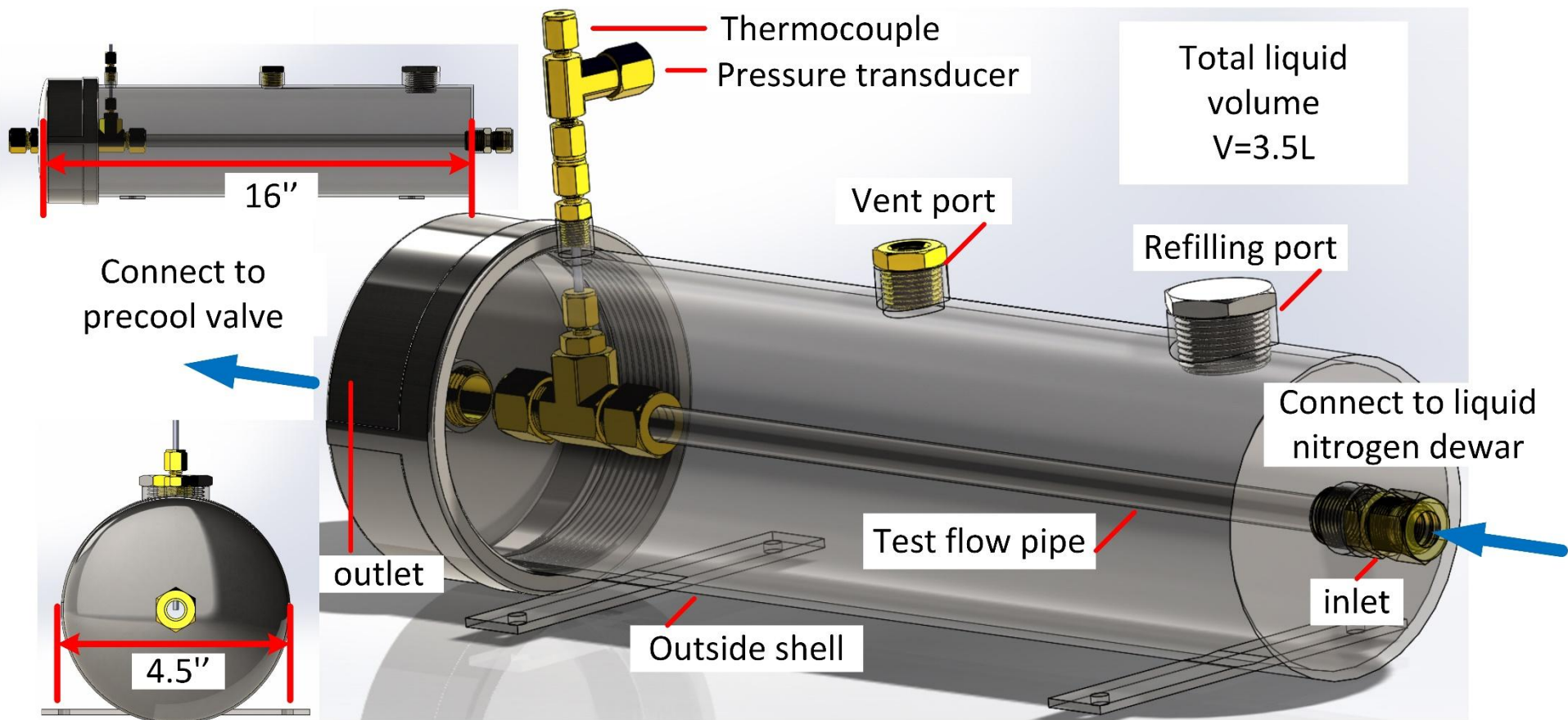
Experimental System

Pool subcooler



Experimental System

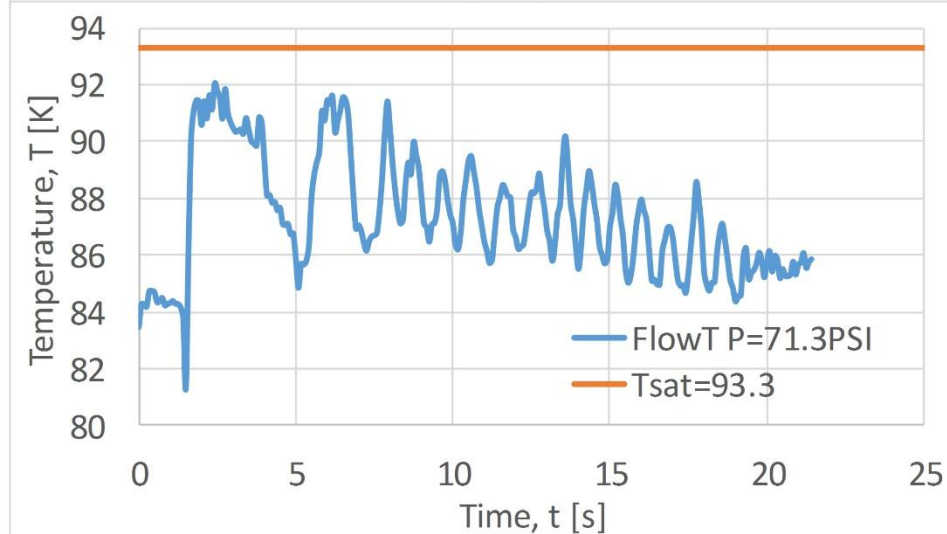
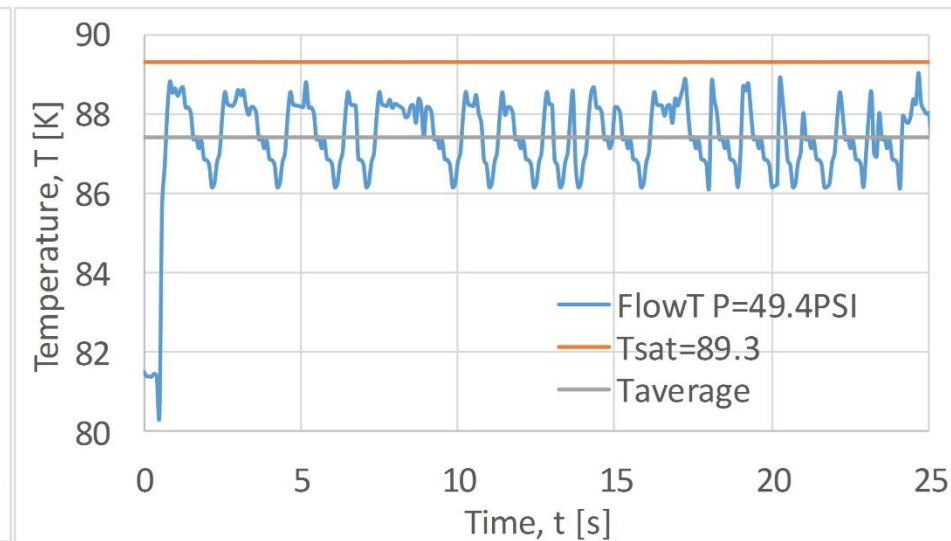
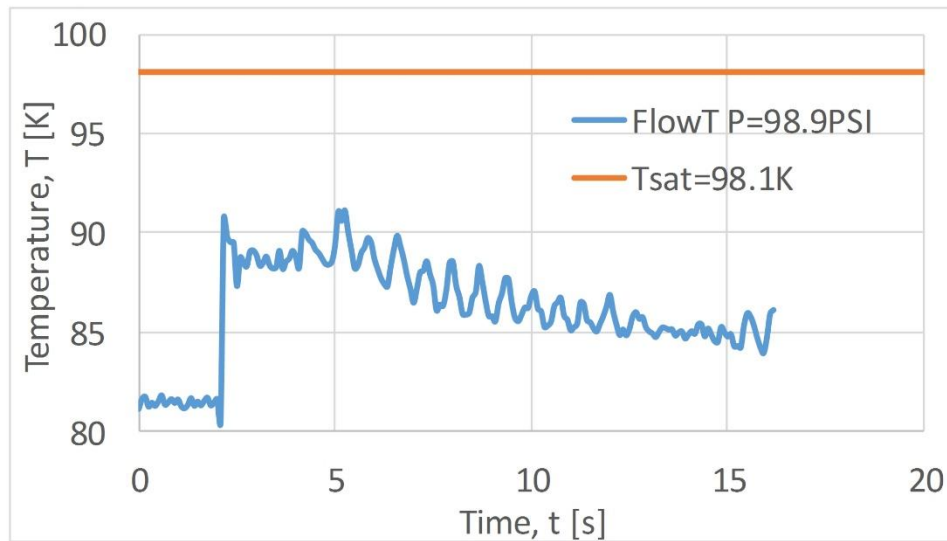
Pool subcooler



Uncertainty: $P=\pm 0.375\text{PSI}$, $T=\pm 0.8\text{K}$

Experimental System

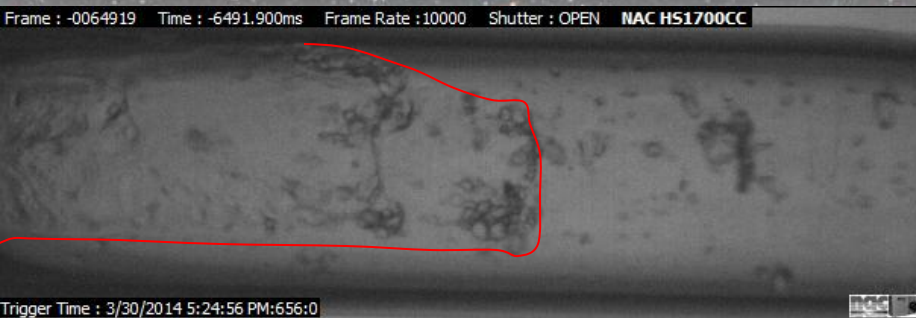
Pool subcooler



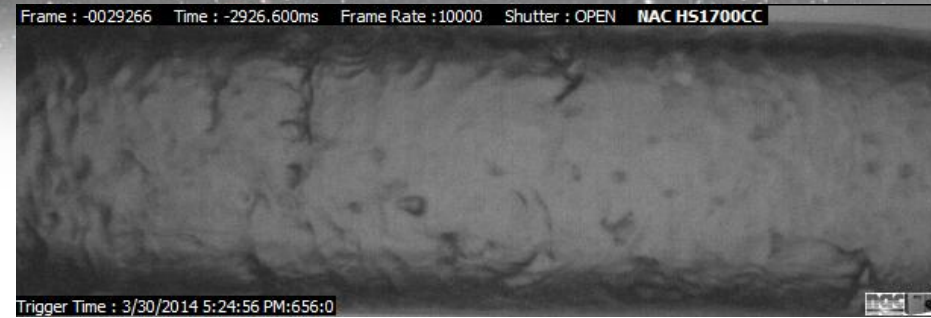
Pressure [PSIA]	Temperature [K]	Re
49.4	87.4+/-1	20100
71.3	87.2+/-5	38700
98.9	86.1+/-6	78600

Flow visualization

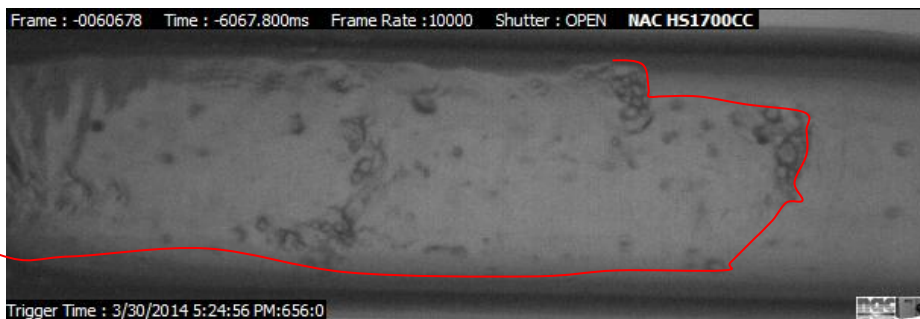
Vertical upward flow



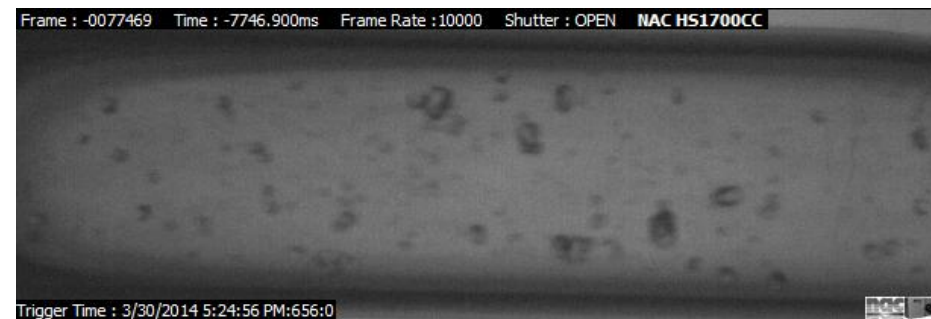
Quench front 1, $t=0$



Pure liquid



Quench front 2, $t=0.42s$

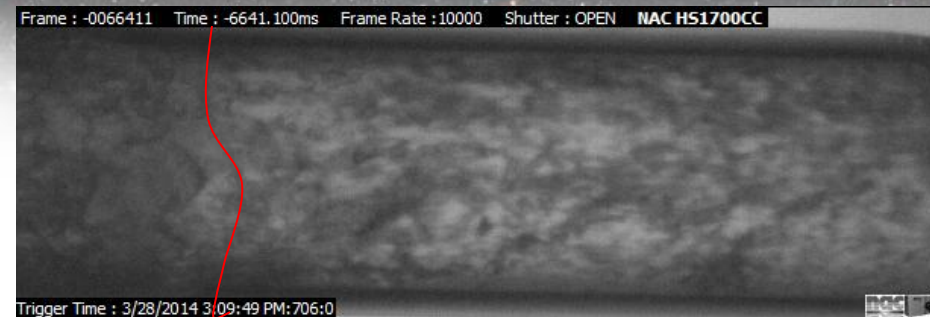


Droplet

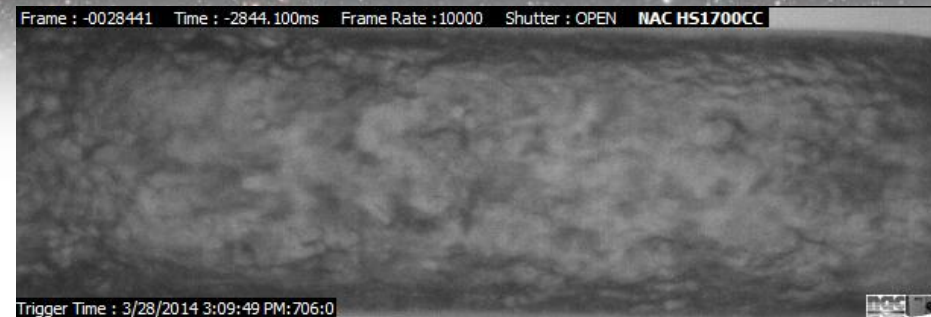
Flow pattern development $Re=1550$

Flow visualization

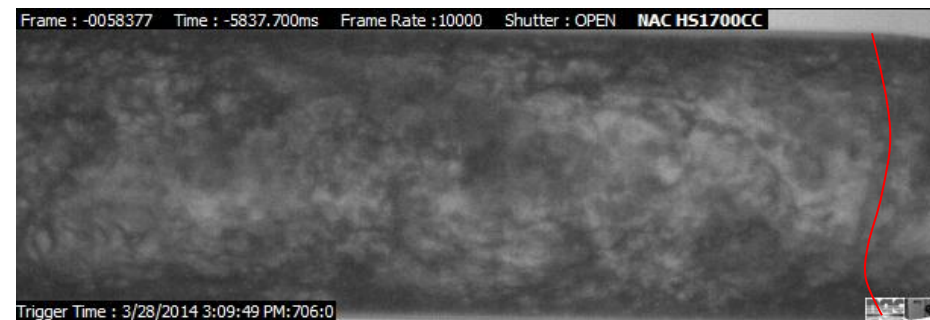
Vertical upward flow



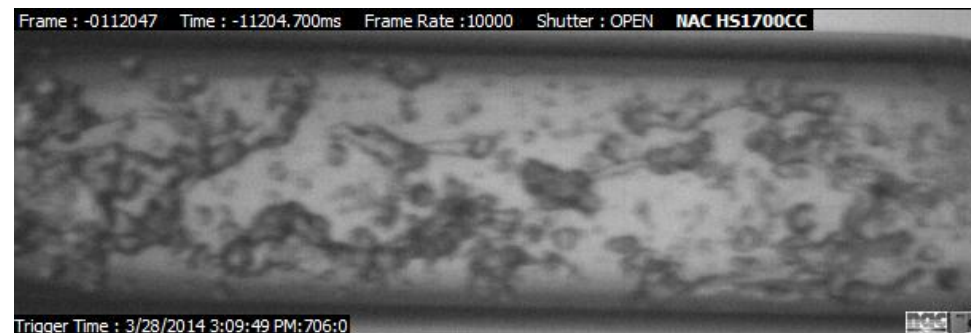
Quench front 1, $t=0$



Pure liquid



Quench front 2, $t=0.80s$

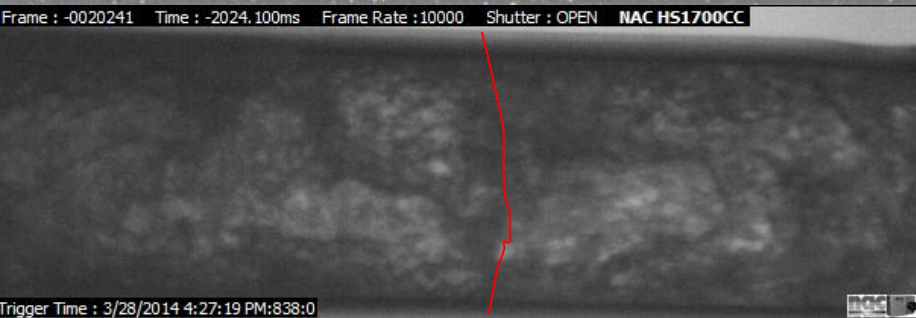


Droplet

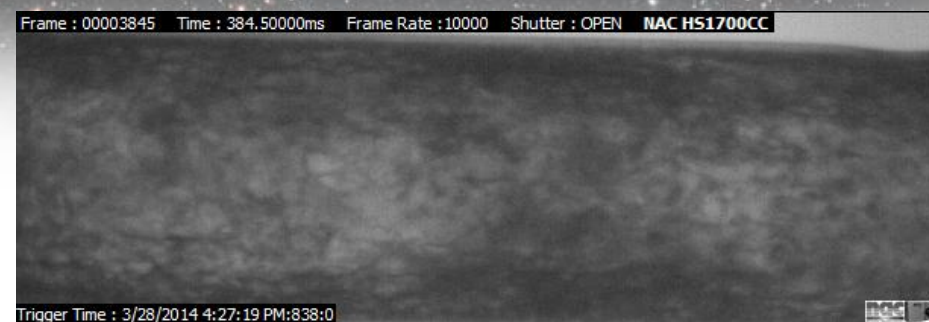
Flow pattern development, $Re=10100$

Flow visualization

Vertical upward flow



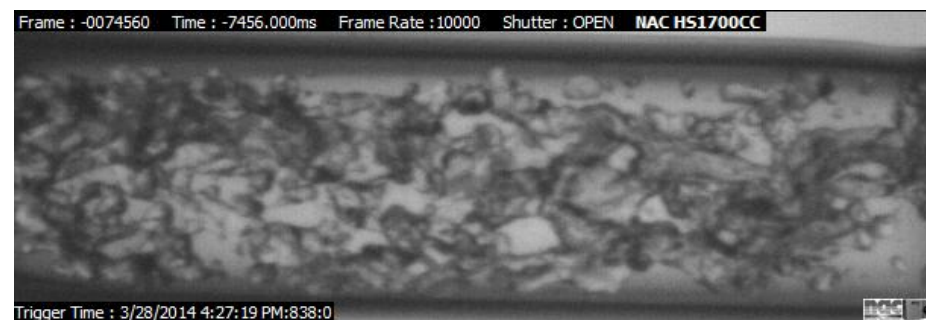
Quench front 1, $t=0$



Pure liquid, high turbulence



Quench front 2, $t=0.30$ s

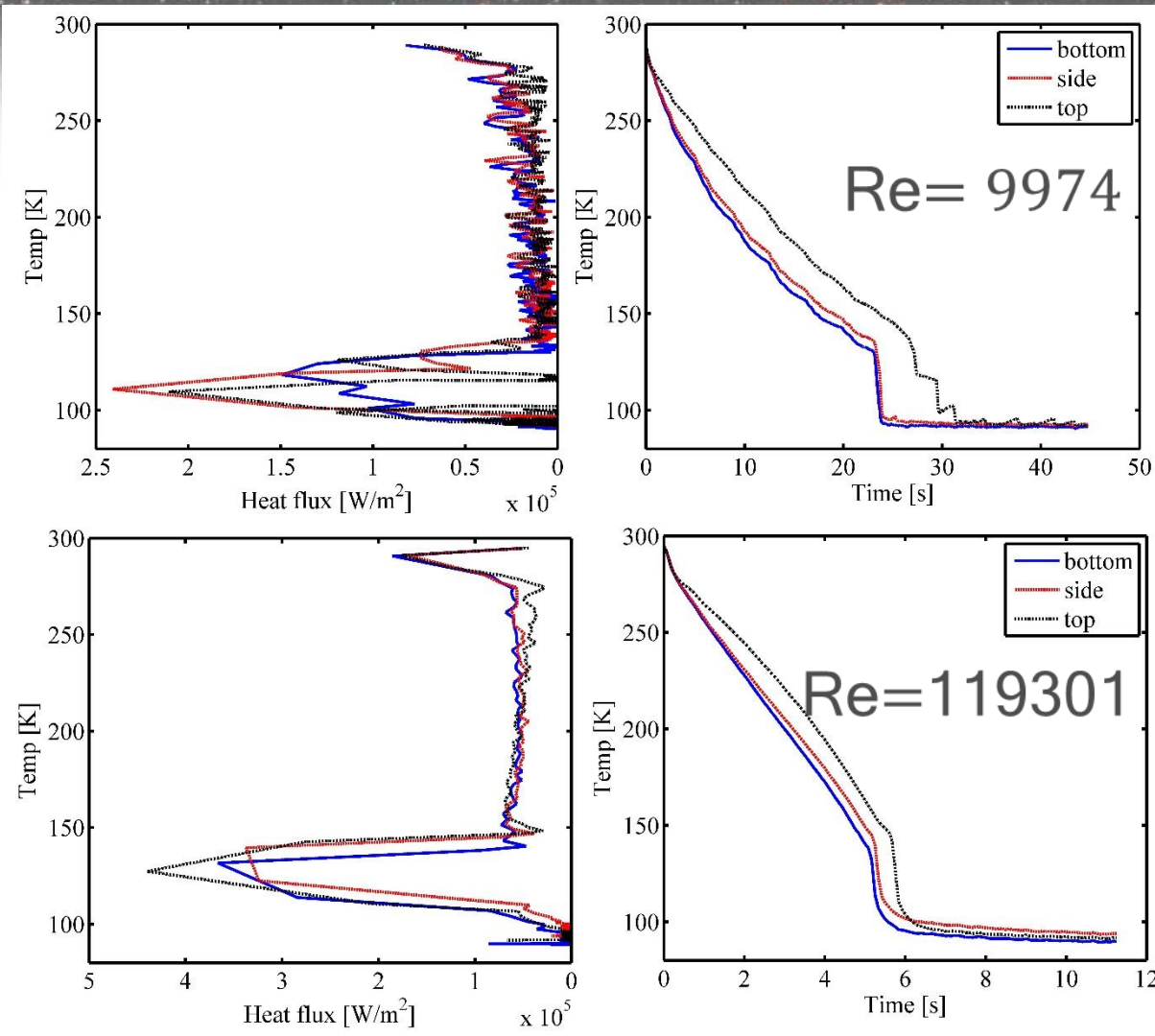


Turbulence inverted annular
flow

Flow pattern development, $Re=36032$

Heat Transfer Characteristic

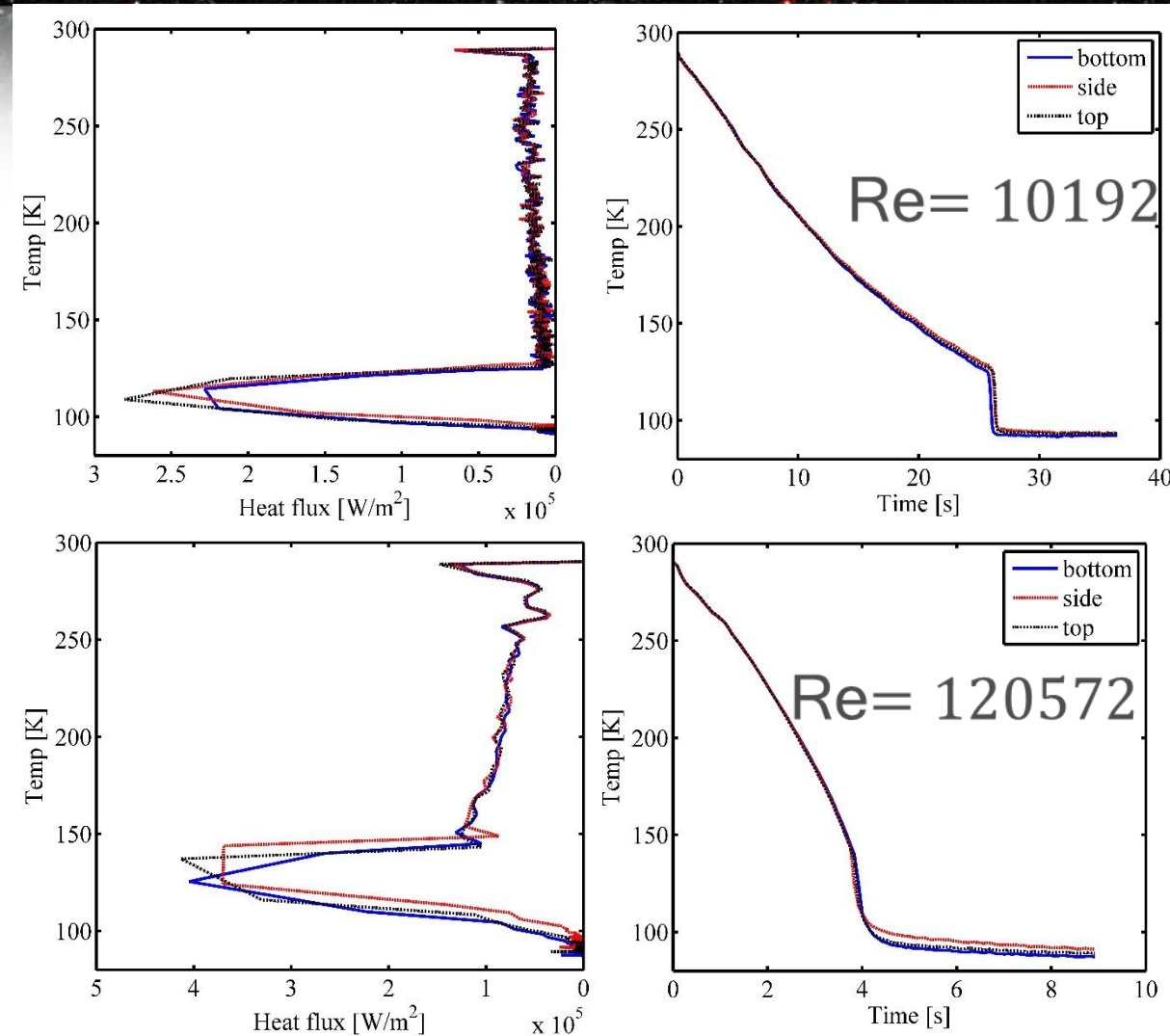
Temperature and heat flux



- Temperature and heat flux curve for $\theta = 0^\circ$
- With increasing Re number, the gravity effect is vanishing

Heat Transfer Characteristic

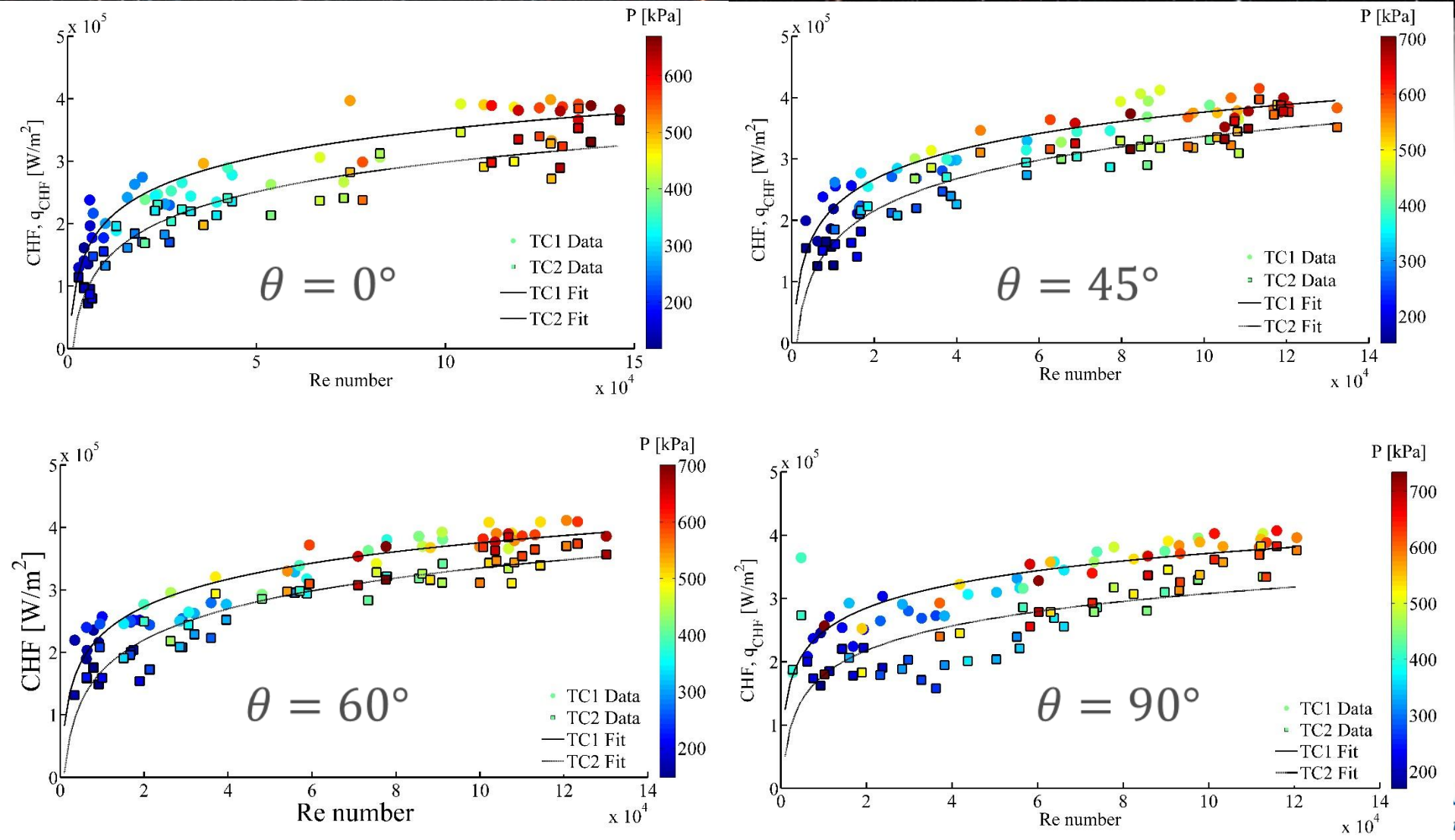
Temperature and heat flux



- Temperature and heat flux curve for $\theta = 90^\circ$
- The three thermocouples have identical readings

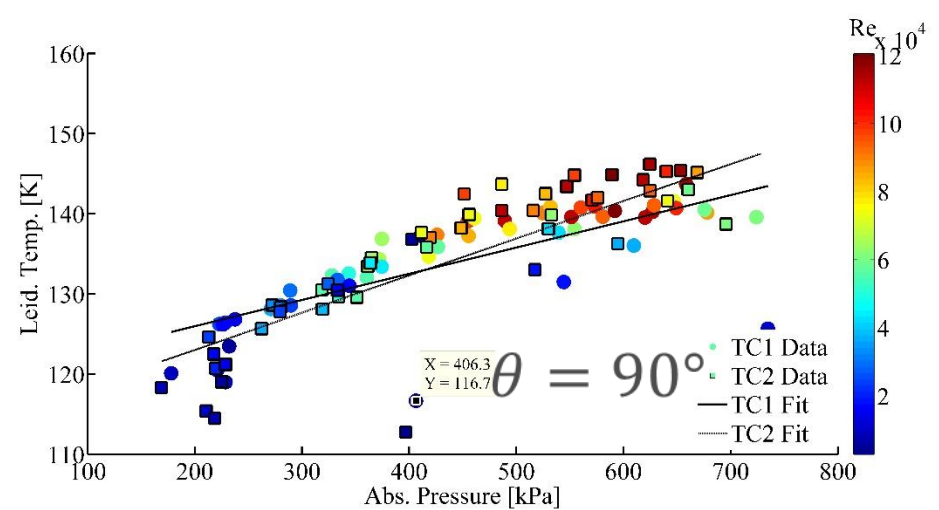
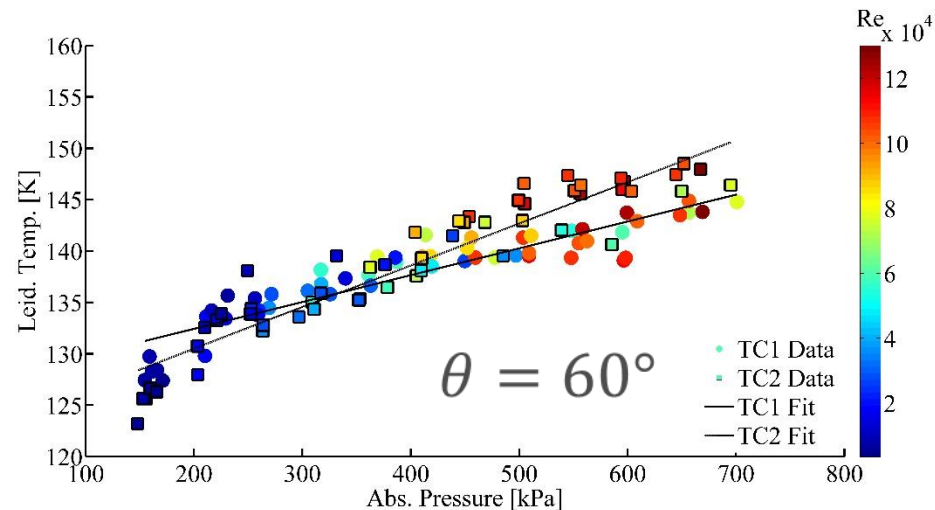
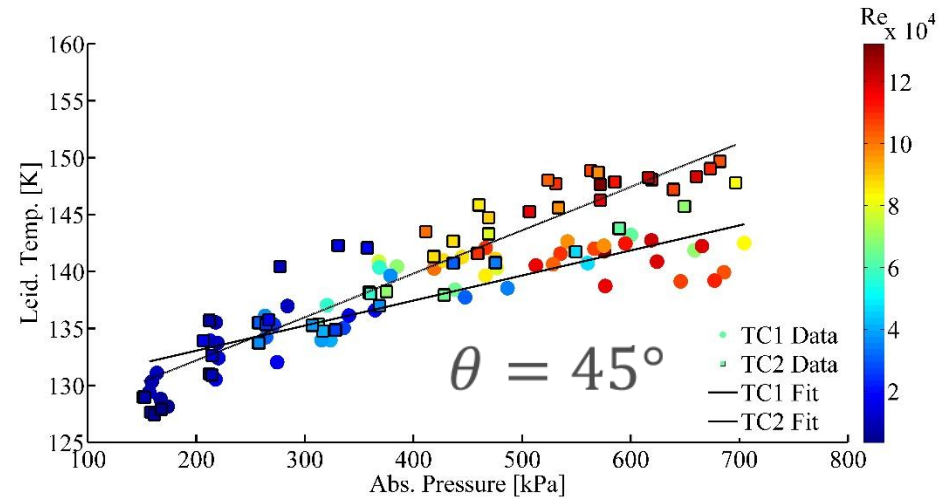
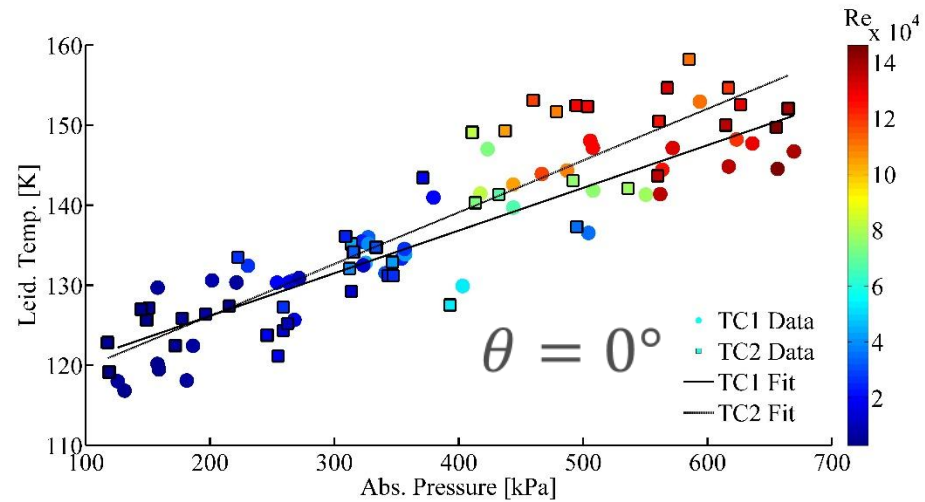
Heat Transfer Characteristic

Critical heat flux



Heat Transfer Characteristic

Leidenfrost temperature



Conclusion

- A stable experiment system is built for liquid nitrogen pipe chilldown experiment covering all orientations, Reynolds number from 2000 to 13000 and pressure ranging from 100 to 700KPa
- The orientations effect will be eliminated by increasing Re .
- In low and medium Re , CHF is heavily dependent on the Re . When Re is high enough, CHF is independent from Re .
- Leidenfrost temperature is always a function of Re .



Thank you